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STATUS OF RESEARCH IN AMERICAN GEOGRAPHY

One of a series of ten reports prepared by Committees of the Division of Geology and Geography, National Research Council, under contract with the Office of Naval Research

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BIOGEOGRAPHY

Hoyt Lemons,
Chairman

DIVISION OF GEOLOGY AND GEOGRAPHY
NATIONAL RESEARCH COUNCIL
WASHINGTON, D. C.

1952

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REPORT ON BIOGEOGRAPHY

of the

COMMITTEE ON PHYSICAL GEOGRAPHY AND BIOGEOGRAPHY

Hoyt Lemons, Chairman

Carleton P. Barnes	John Leighly
Kirk Bryan (deceased)	Luna B. Leopold
C. J. Burke	Jacques M. May
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A. W. Küchler	Richard J. Russell
Douglas H. K. Lee	Laurence C. Stuart

Sir Hubert Wilkins

Division of Geology and Geography

National Research Council

This is one of ten reports prepared to evaluate and describe the current status and future potential of research in various fields of American Geography. The coordinators of the study were Preston E. James and Clarence F. Jones.

National Academy of Sciences - National Research Council

Washington, D. C.

1953

BIOGEOGRAPHY

This chapter in completed form will
have the following page numbers:

INTRODUCTION

This section is not to be included in the volume, and is therefore missing in this preliminary copy.

(Preston E. James, Chairman, Committee on American Geography)

PHYSIOLOGICAL CLIMATOLOGY

As in most fields of scientific endeavor, pure scientific curiosity concerning climate and weather has been spurred, supparted, and largely directed by man's practical needs. Physical methods served other to unravel the interactions of factors responsible for weather and climate and to explain the effect of atmospheric conditions upon the non-living materials so largely used in technological processes. This community of interest, profitable though it was to its sponsors, tended to exclude participation by those not highly trained in physics and mathematics. In the case of plant science, however, so obvious was the influence of climate upon growth and production, that an inter-disciplinary group quickly became established, which could apply the methods and understanding of physical meteorology to the biological problems of plant welfare. The surprising delay of a similar development in relation to the welfare of man and animals may be attributed partly to a bias of animal physiologists against physics, traceable in turn to the close dependence of physiology upon medial schools, and partly to the fact that the effects of climate upon the animal kingdom are less obvious and direct so that there was less economic stimulus to their study.

Physiological Climatology may be simply defined as dealing with the more direct effects of climate upon the physiological behavior of man and animals. It deals, not with the origin of climate or atmospheric conditions, but with their effects when present. It must overlap, as do all scientific fields, with other cognate studies, notably that of Medical Climatology, which deals with the role of climate in the causation of disease. (See Section on Medical Geography). For practical reasons, it extends the term climate to include those aspects of the physical environment which operate in conjunction

with the strictly climatic factors, such as the thermal properties of the terrain and surroundings. Its operation, when fully developed, comprizes three phases: first, an analytic phase involving the environmental factors on the one hand, and the physiological mechanisms on the other; second, a correlative phase dealing with the interaction of the former with the latter; and third, a synthetic phase concerning the consequences of these interactions for the living being as a whole. /1/ Unlike Aphrodite, it did not spring fully-formed from the sea of indifference. There have been many stages in its development, many local growths which have later regressed. It is unlikely that its present form is definitive, but the war years did see a critical change in form which, for the first time, conferred upon it the semblance of a unified, recognizable, scientific field. The workers of the United States and Canada have contributed very largely to this development, especially in its later phases, and it is these contributions which will be emphasized here; but it must be remembered that contributions have been international, and that trans-Atlantic argument has been a powerful factor in stimulating this scientific development.

Examination of Natural Associations

A first step in the consideration of any problem is the examination of actually occurring phenomena, not merely to gain acquaintance with the problem, but with a view to seeking out sequences and coincidences in the events which might indicate associations warranting more careful study. Such correlations between various aspects of climate and man's welfare have been sought from at least the time of Hippocrates. /2/ It was natural that man should be primarily concerned with the more dramatic and more serious effects upon his health, or what we would now call medical geography. It was only as he gained control over these more threatening conditions, that his attention passed on

to the possible association of climate with less immediately pressing disturbances of comfort, productivity, and social behavior. While articulate opinions were not wanting in other countries, it was the American, Huntington, who was most widely hailed as the leader in this search for associations. /3/.

As one method of approach, a search for correlations in naturally occurring events is well justified. But it is only one method; and it carries with it certain inherent weaknesses and dangers. The occurrence of two events in continguity may or may not be due to chance. The frequent occurrence of the two in association lessens the probability of its being due to chance. If in a large series the two are always found in association the element of chance becomes improbable. But before that attitude can be justified, it must be clear that all available evidence has in fact been considered, that there has not been any unconscious selection of data which conform and rejection of those which do not. It must be clear that the individual items are in fact comparable, and not endowed merely with a superficial resemblance. (In this repsect it is not always easy to foresee in what respects the data should be tested for comparability. It frequently happens that what were at first thought to be all apples turn out to be basically cabbages and kings.) Even when the conditions are sufficiently well met for an association to be admitted, it does not necessarily follow that the relationship between the two events is one of cause and effect; it may well be that both are due to a third and unrecognized condition. But perhaps the most important weakness in utilizing evidence of this character in anything but a suggestive fashion is the unpredictability of man's future behavior from his past record. Man is participating in a social evolution of tremendous rapidity, of which only the most general trends are discernible. He is rapidly learning to escape, not

only from the impositions of his physical environment, but also from the inadequacies of his past behavior.

At the time that Huntington commenced his work (1907), data of the kind he needed were not easily obtained, and those that were obtainable were often of doubtful quality. Inductive logic, the process of building generalizations from an accumulation of data, had received a tremendous fillip from the brilliant handling of Darwin; but there was little guidance for those who possessed something less than Darwin's skill in its use. Those to whom Huntington might have turned for guidance in biological matters - physiologists and medical men - were still preoccupied with other tasks or insufficiently advanced in that field to be of much assistance. It is perhaps understandable, therefore, though non the less regrettable, that from a detached study of associations there emerged rather rapidly a full-blown gospel of climatic determinism. Causal relationship was assumed where even association was doubtful. The great importance of culture independently of climate was often forgotten. Categorical statements like the following were accepted as gospel. "The geographical distribution of health and energy depends on climate and weather more than on any other single factor. The well-known contrast between the energetic people of the most progressive parts of the temperate zone and the inert inhabitants of the tropics and even of intermediate regions, such as Persia, is largely due to climate." ("Principles of Human Geography" 1920).

Huntington's deviation from admissible methodology had two unfortunate consequences. So keen is man's interest in his own welfare, and so readable was Huntingtonian prose, that the writings had an immediate popular appeal; an appeal that is still evident. Administrators, sociologists, geographers,

and even medical men read with avidity. For the most part these readers were not in a position to know the limitations of either the evidence presented or the method of analysis. Many found in the doctrine a welcome weapon against the few who had the temerity to challenge the superiority of the European races. There was a strong bond of sympathy between the preacher and the congregation. The minority who protested the method and the validity of the conclusions had little to put in its place. Perhaps through a realization of this, they oftimes made the tactical error of forsaking their position of scientific detachment to take up arms under the banner of "anti-determinism." This was the second unfortunate consequence, for those who could have led the way back won antagonists rather than converts. Devotion clouded judgment, and adherence to "--isms" took precedence over the search for facts. To clarify the issue there was needed a fresh body of enquirers, free from the limitations of past allegiances. As so often happens, a new approach was already in the making at the time when the argument was fiercest. Physiologists, who could have been of little help in the earlier years of the century, had advanced to the point at which they could apply quantitative methods to the study of man's relationship to his physical environment and initiate new lines of enquiry, as well as probe by controlled experiment the suggestions arising from analysis of natural events.

Historical Development

Early Physiological Approach. It is only of quite recent years that there has been sufficient understanding of the basic problem and sufficient interchange of opinion between the various investigators for anything like a systematic attack upon the problems of human adjustment to climatic stress to be recognizable. It is, therefore, better to attempt a description of

developments by categories than in a strictly chronological order. Nevertheless, it should be noticed that, in point of time, America was in the forefront of pioneer studies, for it was as early as 1758 that Benjamin Franklin wrote to his friend Lining of his observations on the cooling effects of evaporation and his conviction that this played a prominent part in protecting man against the ill effects of heat. /4/ By contrast, the oft-quoted accounts of the spectacular and well-designed experiments of Balgden and Fordyce /5/, carried out at temperatures up to 250°F, and reported to the Royal Society in 1774, set out all the evidence a modern student could require to make this deduction inescapable, but did not actually arrive at it. It was from Georgia and South Carolina that Ellis /6/ and Lining /7/ wrote circumstantial accounts of the effects of heat, with a praiseworthy collection of quantitative observations in support.

While Heberden /8/ pointed out in 1826 the necessity for considering humidity in conjunction with air temperature in making an assessment of atmospheric warmth insofar as it concerned man, and Bernard /9/ sketched out a preview of the role to be played by systematic physiology in 1876, it was not until the twentieth century was well underway that a start was made. It was in 1904 that Haldane /10/ made his classic observations in the Cornish tin-mines and in 1911 that Lefevre /11/ published "La Chaleur Animale," in which the quantitative physical approach was for the first time thoroughly expounded. In the meantime, an interest in the energetics of the oxidative processes which are fundamental to most living forms, which had developed out of the studies of respiration of the previous century, had narrowed (largely through the work of E. DuBois /12/ at Cornell, Benedict /13/ at the Carnegie Nutrition Laboratory, and their colleagues) to an intense study of the

so-called "basal" metabolism - the rate of energy production by the resting animal. To investigate the state of the "basal" metabolism under various climatic conditions was an obvious line of enquiry, and in this connection several workers in the American continents, amongst whom Ozorio de Almeida /14/ and E. D. Mason /15/ are best known, showed an apparent fall in the "basal" metabolic rate under tropical conditions. Unfortunately, it now appears doubtful whether measurements made under different climatic conditions are in fact comparable; and, in any case, the actual metabolic rate of natural activity is much more relevant than the "basal" rate in problems of adjustment to thermal stress. Here, as in so many instances, the problem is greatly complicated by the cultural and nutritional habits of the people being investigated. Unfortunately, the word metabolism seems to have acquired an innate virtue in the sight of some who are interested in human climatology but insufficiently versed in physiology. Such are apt to speak of metabolism as a good thing, something of which the more you have the better! Nothing could be less defensible as a general proposition. As with most physiological processes, there is a range which is suitable to the particular individual, rates above or below this not being desirable; and the limits of the range vary greatly with different cases. If there is such a thing as climatic stimulus, and if it does have desirable effects, it is almost certainly not merely through an increase in metabolism.

Attempts to Determine Physiological Significance of Atmospheric Conditions. Probably the most dramatic contribution by American workers to the progress of climatic physiology in the first half of this century was the publication of the "effective temperature" scheme /16/ by a group of investigators working for the American Society of Heating and Ventilating Engineers.

That human comfort and thermal stress depended not on atmospheric temperature alone, but upon the combination of with such factors as humidity and air movement, had been realized for a long time. In 1916 Leonard Hill /17/ had described an instrument, the Katathermometer, which was designed to respond to combinations of these three factors in much the same way as the body; but the limitations of any simple instrument in imitating the reactions of the human body were clearly apparent, and the ASHVE workers adopted a different approach. Using the human body as the measuring instrument, they mapped out combinations of dry bulb temperature, wet bulb temperature, and air movement which resulted in similar sensations of comfort or discomfort. Upon the basis of these results they drew up a nomogram from which there can be read off the temperature of a still, saturated atmosphere which would have the same effect upon comfort at any given atmosphere for which the three quantities are known. This they called the effective temperature of the atmosphere.

This scheme gave, at least to those concerned with indoor conditions, a measure of assessing the combined effect upon man of the three most important variables affecting thermal balance and comfort. The scheme had certain inherent limitations, which are sometimes less clearly recognized by the users than they were by the inventors. It also had certain errors at the extreme ends of the scale. But it remains today the most practical method of determining the thermal significance of indoor conditions. The major restrictions of its use under outdoor conditions are the exclusion from consideration of all but the simplest corrections for radiation exchange, and the condition that the person shall be either clad in a medium weight suit or stripped to the waist.

In the meantime, Winslow and others /18 a & b/ at the Pierce Laboratory

of Hygiene, New Haven, had been investigating further the idea of instrumental assessment, but abandoned it as being impracticable. In the course of their investigations, however, they were led to study the partition of heat exchange between the human body and its environment amongst the channels of radiation, conduction-convection, and evaporation-convection. This in turn led them to two concepts which are important in theoretical considerations of heat exchange and thermal stress: that of the "percent wetted area," and that of "operative temperature." While the skin may sometimes be completely wet, it is never completely dry. At any one time, if the numerous small areas of water film on the skin were added together they would constitute some important fraction of the total skin area. This gives a physical concept of what is meant by "percent wetted area" /19/, and enters into calculations of heat exchange. For any situation in which the walls and air are at different temperatures, there is another situation with walls and air at the same temperature which would result in the same exchange of heat with the naked human body. The common temperature of this second situation is, briefly, the "operative temperature" /20/ of the first.

The Pierce Laboratory work dealt primarily with the naked man, but practical considerations called for quantitative methods of dealing, not only with clothed man, but with the significance of the clothing itself. In 1941 the concepts used in the Pierce Laboratory were first extended into this field with the definition of the "clo" unit as the unit of insulation /21/, and its application by Burton /22/ to the determination of clothing requirements for men at different degrees of activity in different thermal environments. At about this time a "tog" unit was proposed by British workers, but it did not gain general acceptance, although it was defined in more classically physical

terms. To the fundmental expression Burton added a term for radiation exchange and devised a parallel set of expressions for dealing with heat exchange by evaporation-convection and the effect of clothing thereon.

The adoption of the ideas so developed for the systematic treatment of clothing problems came as the result of a conference held in 1944 on "The Principles of Environmental Stress on Soldiers" under the auspices of the Climatology and Environmental Protection Section, Office of the Quartermaster General /23/. The principles set down then still dominate fundamental considerations of heat exchange between man and the environment, though many special considerations have been added since, and integration has frequently to be made with considerations which can be defined at the best only in quasi-quantitative terms.

As an offshoot of the Quartermaster conference, interest has continued in an idea of an index of climatic stress and strain which would be more fundamental in its development and wider in its application than the effective temperature index or other current suggestions for conjoint assessment of thermal factors in the environment. The difficulty lies, not so much in calculating the applied thermal stress, as in determining the physiological significance of a given stress, and deciding the extent to which relative contributions by the stress-producing components as well as the total stress affect that significance. Time will reveal the extent to which these quests will be successful.

<u>Systematic Study of Human Reactions to Climatic Stress.</u> While the generalists have been seeking the touchstone which will reveal the true significance of any set of environmental conditions, systematic physiologists have been going about their normal business of describing in greater detail

the specific responses of the human body to various environmental situations, and in working out the mechanisms responsible for such responses. The Harvard Fatigue Laboratory served as the focal point in the 1930's, but the central figure in later investigations in the western hemisphere has been H. C. Bazett, whose death on his way to the International Physiological Congress in 1950 brought to an end a period of one of the most stimulating careers we have been fortunate to experience. More than any other, by virtue of personal example, constant visiting, and continual stream of ideas he brought American, Canadian, British and even Australian investigation during World War II to some semblance of united effort, and prompted an understanding of problems amongst all these workers which might never otherwise have developed. /23,24/.

The list of war-time contributors is long, but the two most outstanding contributors in this hemisphere to the applied aspects are E. F. Adolph, who applied laboratory concepts and methods to studies in the natural environment, especially of a hot-dry character /25/, and S. Robinson, who directed both laboratory and field studies of warm humid environments /22/. Of similar caliber, and sometimes integrated with the studies just mentioned, were the team investigations carried out at the Armored Medical Research Laboratory /26/, mainly on heat problems, and those at the QM Climatic Research Laboratory /27/, especially on effects of cold conditions.

Since 1945 the pattern of activity has changed somewhat, with a proportionately greater emphasis upon organized field trials, and the restriction of most of the activity to service agencies or institutions linked to service requirements by contract. Various centers in Alaska and Fort Churchill in Canada have witnessed many studies by service groups from the USA and Canada, while Death Valley, California, was the scene of a hot weather study

by a Quartermaster group in the summer of 1950. In these studies, opportunity has been taken not only to test materiel, and to collect factual data, but also to develop new or improved field techniques and to conduct basic research.

Practical Applications

Applications to Clothing and Housing. There is no doubt that in the field of physiological climatology the demands of practical problems have greatly increased the effort expended in research and accelerated the pace of development. While immediate practical demands may at times draw more rapidly from the stockpile of knowledge than additions are being made, the opportunities for such additions are in the process being maintained at a higher level than would otherwise be the case. It is instructive, therefore, to look at the extent of the applications of this knowledge to such eminently practical requirements as clothing and housing.

It is fairly certain that the clothing and housing adopted by a people who have had centuries in which to work out a pattern of adjustment to a particular climate will be fairly close to the optimum protective requirements that can be wrung by their culture from available resources. To that extent native practices represent adequate adaptation. But in so far as the Americas are concerned, neither culture nor resources have remained static. There is here an increasing desire to bring actual attainments as close as possible to the ideal, and as rapidly as possible, cultural and material limitations notwithstanding. American eyes, furthermore, are being increasingly turned to regions beyond the seas, whence new suggestions flow and to which the lessons of advanced technology are in turn being directed. Under these circumstances, it becomes more and more essential for Americans to understand

just what requirements are imposed upon clothing and housing by the climatic conditions, just what features are cultural rather than obligatory, within just what margins individual caprice may be safely indulged.

Both the realization of this necessity and opportunities for its satisfaction are of quite recent development. While the more straightforward requirements and methods have been known from the turn of the century, it is the development of a systematic appreciation of thermal physics by a wide range of operators - physiologists, designers, administrators, and geographers in addition to engineers, climatologists, and architects - which has brought sufficient unanimity of thought to make concerted development possible.

In relation to clothing, there is only one comprehensive book available, /22/ and that was published only in 1949. But a study of this book will reveal that it is now possible to make a very good estimate, for example of the amount of insulation that clothing would have to provide in a given cold environment to maintain comfort in a man carrying out a given degree of activity; or, conversely, the maximum activity that would be permissible for a man wearing given clothing in a given hot environment. It will reveal further that the relative contributions of yarn, weave, thickness and design to the insulation, or to the impedance offered to evaporation, by a given set of clothing can be determined. The basic principles are known, and are available in forms suitable for use by a variety of interested people. There are numerous details which could be improved, and much in the way of basic data which needs to be ascertained before the principles can be applied over a satisfactorily wide range of problems; but the principles are there, the methods exist, and the need is felt. There seems little reason to suppose that workers will fail to materialise in proportion to the demand for their

services.

The names of many who participated in this development have already been given, but to these should be added that of Siple, who was largely responsible for the comparatively early interest taken in this approach by the Quartermaster General's Office of the U. S. Army as well as for early stimulation of the scientific findings. It is to Siple, also, that the credit must go for showing how basic clothing requirements for an area could be determined from a knowledge of the climatic conditions prevailing, and estimates of this character plotted on regional maps or compiled in tables to constitute a clothing almanac. The interest started by him has been continued in the Environmental Protection Branch the Quartermaster Research and Development Division /28,29/ with considerable attention to the integration of climatic conditions on the one hand and human requirements on the other, in the determination of clothing requirements.

In the matter of housing, there is still no comprehensive book available corresponding to that cited for clothing, but the availability of principles and their application to regions of the United States has been demonstrated in somewhat different form. In roughly alternate numbers of the Bulletin of the American Institute of Architects, commencing in September 1949, there have appeared regional tables under the title of Climate Control Project /30/. Each set of tables first indicates diagramatically the frequency of occurrence of individual values of such variables as temperature, solar radiation, cloud, precipitation, relative humidity, vapor pressure, wind force, etc., month by month in a central location for the particular region. Other diagrams indicate the extent to which zones about the central location might be expected to differ from it. Then the significance of the distribution of each variable for each of several key features of housing is given in tabloid form. Sponsored by the

magazine "House Beautiful," and directed by a board of well-known persons (R. Linton, H. Landsberg, L. P. Herrington, W. A. Taylor, D. Coman, and M. L. Colean), it illustrates graphically and forcibly what can be done by any country which has available adequate meteorological data and the means for processing it.

Activities conducted by the American Society of Heating and Ventilating Engineers, by individual members of the Society, and by Herrington and colleagues at the Pierce Laboratory of Hygiene, combined with studies in other countries have been largely responsible for the basic information upon which to base the recommendations for the adjustment of housing to climate. In the U. S. A. the Bureau of Standards serves in somewhat the same way as the government-sponsored Experimental Building Station in England, Australia, and South Africa, which are equipped for laboratory and model investigation, and participate in large-scale testing of ideas and practices through government-financed housing schemes, and furnish opportunities for the utilization of interdisciplinary research results in the framing of building codes for both governmental and private use.

<u>Applications to Animal Industry</u>. While consideration of the role played by climate in the general field of animal ecology rightly belongs in zoogeography, the biophysical approach which has advanced our understanding of man's reactions to climatic stress is now being applied to problems of animal production, and the course of this development may very well be traced here.

Although it has been known for a long time that domestic animals of highly selected mid-latitude breeds often deteriorate when introduced into sub-tropical and tropical climates, the cause has remained conjectural and corrective measures a matter of marked dispute. The most cursory analysis

of the problem indicates that at least three major groups of factors call for consideration in such transfers of livestock - climatic, nutritional, and infective. Veterinary medicine was not slow in recognizing the tremendous improvement brought about in human medicine about the turn of the century by the study of infective pathology, and the potential significance of the method for treatment and prevention of stock disease. The significance of climatic factors for the transmission and development of many types of infective disease was similarly transferred, with the early development of a climatic pathology of domestic animals. In the case of nutritional factors, however, attention seems to have been concentrated more exclusively upon mid-latitude conditions, and knowledge has remained relatively poor on what may be involved in introducing to the nutritional circumstances of the tropics animals which have been highly selected over a hundred years or more for the relatively stable and lush pastures of mid-latitude regions. This gap in our understanding is gradually being closed, however, as the techniques of nutritional investigation developed in mid-latitude countries, in which American workers have played no small part, are applied to problems in various tropical and sub-tropical regions.

Questions of direct climatic effects have, however, been left largely unexplored, some adopting the position that such direct effects are relatively unimportant, others accepting the view that they are of major consequence and inescapable. For the latter, and it is not difficult for them to secure evidence which at first sight supports their pessimism, there were two alternative actions. The first was to cease important mid-latitude animals, and to concentrate upon breeding up desirable qualities in "native" stock, in the same way as that was done to obtain our present mid-latitude types. The second was to try to concentrate both the desirable production qualities of the

mid-latitude animals and the tolerance qualities of the native animals by inspired cross-breeding.

To either of these programs, and both have certain merits, the biophysical approach can offer assistance and suggestions. That certain individual animals have a superior tolerance to heat stress is fairly easily demonstrated. That types or breeds vary in their mean or characteristic tolerance has been established both in the laboratory and in the field. But just why one individual type, or breed is more tolerant than another has not been satisfactorily worked out. There seems no good reason why this should not be done. It appears reasonable to suggest that breeders would be able to direct their programs, select their breeding stock, and perhaps even discover superior genotypes if they could recognize in their individual animals those characteristics, anatomical or physiological, which determine degrees of climatic tolerance. Guesses have been made, and most of those items which would be suggested by a study of the basic physical processes involved have been named. Little attempt has been made, however, to determine systematically the relative importance of such things as variable blood-flow through the skin, extent of surface area, insulative properties of coat, density and functional capacity of sweat glands, respiratory cooling, degree of activity, mechanical efficiency of activity, and endocrine control of metabolism.

The central idea, however, has been accepted by such influential organizations as the Bureau of Dairy Industry (U. S. Department of Agriculture) and the Food & Agriculture Organization of the United Nations /31/. The former has a program of investigation in hand, which will apply this line of enquiry to dairy cattle. The latter has made it one of the major items at two international conferences on animal production, one at Lucknow in India /32/, and one

at Turrialba in Costa Rica /33/. Through the latter organization studies in animal climatology in both the field and the laboratory have been encouraged in different parts of the world, and provision made for facilitating the exchange of information between the workers themselves, and between the scientists and animal producers.

The outstanding American pioneers in this field are S. Brody and A. O. Rhoad. From a study of the energetic efficiency of stock i.e. the energy value of the meat, milk, or work produced by the animal in comparison to the energy value of the food consumed, Brody naturally passed to considerations of the influence of climatic factors thereon. His book "Bioenergetics and Growth" /34/ is the only text available and will remain a rich reference for a long time to come. His climatic laboratories at the University of Missouri are the most complete of those devoted to animal climatology. Rhoad has emphasized field work, and is best known for his "Iberia Heat Tolerance Test" /35/, which provides an approximate method for determining the tolerance of a number of animals under field conditions. With developing interest other centers have started work, notably the University of California Agricultural Experiment Station at Davis, where Kleiber's basic work on metabolism has been extended by his colleagues to questions of partitional calorimetry under different environmental conditions. Through the interest of the Bureau of Dairy Industry, other institutions are being brought into collaboration on both the physiological and the climatic aspects; especially in the south-eastern states.

The Regional Concept and Physiological Climatology

Geographic thought naturally tends to group phenomena by regions, whether defined by the phenomena themselves, or by their relationship with other phenomena already regionally demarcated. The tendency of plant life to exhibit

regional distribution led Köppen, and later Thornthwaite, to develop classifications of climate which would correlate with such distribution; and it might be thought that similar associations would have provided a stimulus to regional classification of climate in so far as it affects man and animals. That such classifications for animal climatology have not developed beyond the simpler pragmatic stage is probably due to the fact that the association of man and animal with climate has been developed, not so much by the zoologist, as by the physiologist, who is interested more in processes than in the distribution of species, even when the species is man.

The physiologist feels that a rational, as opposed to an empirical, classification of climatic significance for man could be sought only for those effects which have a definable and quantitative relationship to measurable climatic factors. In the present state of our knowledge, this would be permissible only in respect to the heat balance of the warm-blooded animal. For other processes, such as behavior, infectious disease, productivity, cultural development, he feels that the antecedents are so complex, measurements so difficult, and distribution determined by so many specialized factors, that quantitative classifications are out of the question.

Even within the limits of heat balance, the physiologist has pursued a somewhat different approach from that adopted in plant climatology. He sees the thermal balance of the body affected by four simultaneously acting climatic elements: air temperature, vapor pressure, air movement, and radiative state of surroundings. These are separate physical entities, but they all operate through their effects upon one bodily process - loss of heat to the environment. They are thus interchangeable, and a situation can be characterized when they are all simultaneously known, but only when they are all simultaneously known.

Most physiological thought has tended, therefore, to concentrate upon establishing an index of composite thermal stress, or better still, an index of resultant thermal strain. The difficulties that this approach is presently facing have been mentioned above.

It is doubtful, however, if conservatism would cease even if an acceptable index of thermal strain were established. It is probable that there would continue to be a resistance on the part of physiologists, who regard variation in response and, for that matter, variation in stress-producing climatic elements, as continuous processes, capable of subdivision only at the peril of the subdivider. Not that they would prohibit subdivision, simply that they would regard any subdivision as a purely arbitrary and pragmatic affair, suitable at best only for the purpose for which the subdivision was made. Even then, they would prefer to use transition zones rather than linear or point boundaries, and keep the number of subdivisions small. Within these limitations subdivisions have been made, with the assistance or acquiescence of physiologists as, for example, the clothing zones constructed by the Office of Quartermaster General /29/.

Of more far-reaching importance, however, is the integration of knowledge concerning the reactions of men and animals to climatic stress with that concerning other interactions which have an important bearing upon the history, present condition or potentialities of a region, especially with reference to

human occupance. The physiologist may well feel that his competence and even interest stops with the transference of discussion from the physiological reaction to social significance, and in this he may even be accompanied by the physiological climatologist. It is here that we encounter what may be the crucial epistemological problem of our age. It is comparatively simple to break a problem up into component parts, for each of which a pre-existing discipline of thought exists. And even where one does not exist, it is not long in our highly scientific and technical culture until a discipline is developed to meet a need. Deductive thought has always been simpler than inductive, and scientists are always more ready to probe more and more deeply on a narrowing front than to range over a wide field in which thought must be synoptic. But practical demands require that synoptic judgment be made, that the specific answers to specific studies be somehow integrated to give unified answers to the original unit problem. Older scientists discourage the younger from adopting interests in which energy may be dissipated, and are apt to be suspicious of those who reason in a field in which conclusions are so difficult of verification.

The dangers are real, but integration must be effected. It is much more desirable that the integration be made by those who are familiar with the detailed analysis, than by the uninformed, the superficial, or the irresponsible. How is this to be done? To take the case in point, how are the facts and ideas deriving from geographical, physiological, anthropological, economic, sociological, political and agricultural investigation to be put together in a form which can be used by administrators, politicians and statesmen who have to make the judgments and direct action which will be in accordance with the best interests of the region and its people? To rely upon the emergence of

extraordinarily gifted leaders is both unrealistic and escapist, though such men would provide significant impetus when and where they chanced to occur. There is required a mode of thought and machinery for its realization. From our schools through to the highest deliberations of the land, the methods, checks and limitations of synoptic thought should be taught, encouraged, and practiced. Teachers, tutors, project leaders, administrators, and executives can set the stage, being successively producers, audience and critics until sublimination of the actors to the performance becomes the accepted creed. This can be done; but it requires faith, insight and patience. Only when it is accomplished will it be possible for questions of occupance to be answered as such and not with unrelated and conflicting recommendations from a bevy of ruggedly independent scientific groups.

Summary of Present Position

A mode of thought has been established in which approaches characteristic of the climatologist, physicist, physiologist and geographer have been integrated in a study of the adaptation of man and other warm-blooded animals to climatic conditions. This centers around the heat balance of the animal, the effect that thermal conditions in the environment tend to have upon that balance, and the adaptations made by the animal body to offset those effects. In at least general form it is expressible in quantitative terms, and permits the thermal stress to be calculated for given conditions of activity, clothing, temperature, humidity, air movement and radiation.

The nature of the strains resulting from the application of thermal stresses are known, and are referable to them in a general quantitative sense; but a satisfactory method of adequately assessing the physiological significance of thermal stress has yet to be determined.

Important practical applications of this rather new field of scientific endeavor have already been made to problems of clothing, housing, and animal production, with the introduction of quantitative and predictive methods where reliance had formerly to be placed upon the empirical or traditional.

The geographic distribution of climatic elements determining thermal stress is becoming better known, but few attempts have yet been made to map the distribution of their combined significance or resultant physiological strain. Some attempts have been made to integrate the knowledge made available through the approach of physiological climatology with that from other approaches to the complex problems of regional occupance; but wider appreciation of the implications of synoptic thought and deliberate cultivation of its practice are required.

As with any new field, there is an acute need of recruits; but there is an especial need of recruits with insight and faith as well as ability and patience.

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MEDICAL GEOGRAPHY

There seems to be a great need today for a precise definition of medical geography and for an evaluation of the techniques and potentialities of the field. For too long medical geogrghy has been identified with an aggregate of loose impressions and hypothetical correlations between the occurrence of certain pathological phenomena and environmental circumstances. Yet we feel that studied with sober discrimination, such correlations can shed considerable light on the occurrence of disease.

"In the earliest days of medicine physicians knew little more about the causes of disease than the place where they occurred." (Even today the geographical or locational factor is, indeed, one of the few facts known about some diseases and is reflected in the name given to the disease - for example, bunyamwere fever, Wumba fever, Semliki Forest fever, Colorado tick fever.) "Environmental factors had during the first centuries of medical knowledge, an importance which they lost when Pastorian discoveries focused attention on the study of pathogenic organisms. With further progress a renewed interest in environment developed, for it became clear that the organisms themselves were closely related to the milieu." /May, Scientific Monthly, 1951).

Definitions

In 1795 L. L. Finke of Lengerich, Germany, gave one of the first definitions of medical geography. To this author medical geography was the description country after country of its position, soil, air lightning, foodstuffs, mode of living, customs and habits of the people, insofar as all these factors have a bearing on health and disease and on local therapeutics.

In modern time, again in Germany, Zeiss, who liked to think of himself as the father of medical geography, declared in 1932, "By geographical medicine or geomedicine is understood the branch of medicine which attempts to clarify

and explain the results of medical research by geographical and cartographical treatment. By <u>medical geography</u> is understood the branch of geography which attempts to study and explain the effects of geographical space, earth, and its vital forms, on man, animal, and plant."

<u>Proposed definition of medical geography</u>

"Parasitology, epidemiology, and medical entomology take into consideration some aspects of the relationship between disease and environment. Medical geography professes to make the study of these relationships its principal objective." (<u>ibid</u>).

Our approach to medical geography can be summarized as the study of the distribution of manifested and potential diseases over the earth's surface and of factors which contribute to disease (pathogens), followed by the study of the correlations that may exist between these and the environmental factors (geogens).

<u>Objectives and methods of medical geography</u>

"The first aim of the medical geographer is to map the distribution of diseases throughout the world. It is not possible to study the influence of environment on diseases if we do not know <u>who</u> has <u>what</u> and <u>where</u>. Once the person, disease, and place are known, we may be able to understand why someone is afflicted and someone else is not. Geographical factors may emerge as paramount in the creation of the pattern of distribution. The measurement of the importance of these factors is the second aim of medical geography. It is thus a study of correlations." (<u>ibid</u>.) To do this successfully the various factors which combine to produce the pathological complex on the one hand, the geographical environment on the other, should be assessed and, if possible, scientifically measured. This Hippocrates could not do. It looks as though

technology had very nearly caught up with the ambitions of our predecessors and as though it might now be possible to get the real, but concealed, picture of diseases which our precursors lacked.

We suggest that the methods to bring about these results could be:

a) sample studies of populations to build the picture of the extent of the exposure

b) analysis of the influence of each element of climate (as far as it is possible to isolate them) upon the various pathogens

c) synthetic regional studies to show where groups of diseases are fostered by the combined action of climatic factors.

Medically Significant Factors

The study of geogens lies in the province of pure geography. Therefore, since we are concerned with the marginal region between geography and medicine, we shall merely list the geographical factors, or geogens, and direct our attention to a discussion of pathogens - mentioning geographical factors only insofar as they exert an influence on pathogens.

Geographical factors, or geogens /2May, G. R., 1950/.

1) Physical

- Climate
  - Latitude
  - Rainfall and humidity
  - Temperature
  - Barometric pressure
  - Sunshine and cloudiness
  - Wind direction and velocity
  - Radiation
  - Static electricity
  - Ionization
- Relief
- Soils
- Hydrography
- Terrestrial magnetism

2) Human or social

- Population distribution and density
- Standard of living

Housing
Diet
Clothing
Sanitation
Income
Communications
Religious customs and superstitions
Drug addictions

3) Biological
Vegetable life
Animal life, on earth and in water
Parasitism, human and animal
Prevalent diseases
Dominant blood groups

Pathological factors or pathogens

Disease is the name we apply to the signs of suffering of living tissues (pathology). For the purpose of medical geography it is convenient to divide human diseases in two groups:

a) diseases occurring as the result of the aggression of other animal or vegetable organisms. This group comprises the communicable diseases.

b) diseases occurring without the aggression of other animal or vegetable organism. This group can be subdivided into two groups, namely:

1) diseases due to tissue changes which are essentially reversible by spontaneous physiological adjustments. These should fall under the study of physiological climatology (see Douglas K. Lee's chapter)

2) diseases due to changes which are essentially nonreversible.

Pathological factors, or pathogens, can be tentatively listed as: causative agents, vectors, intermediate hosts, and man. Although the latter can become sick in his capacity as intermediate host or definitive host, he is a member of the complex, and geographical factors govern his susceptibility to disease.

Pathogens of communicable diseases

The causative agent of a disease can be introduced in the human body directly as are the agents of epidemic meningitis, cholera, tetanus, typhoid

fever, tuberculosis and many other diseases. They can be inhaled, ingested, or introduced through wounds or abrasions. In other instances the causative agent is introduced in the human body through the offices of a vector. In some cases the larval stages of agents require the shelter of an intermediate host to develop. Finally, vertebrates other than man may serve as a habitat to an infective agent and help support its life cycle, spreading at the same time its numbers and density in nature, thus enhancing the possibilities of epidemics.

This biological phenomenon allows a classification of diseases into two- or multiple-factor complexes, which facilitates their study from a geographical point of view. Each of these factors, including man himself, is closely linked to the geographical environment. The occurrence of disease at a given spot is the result of a combination of geographical circumstances which bring together agents, vectors, intermediate hosts, reservoirs, and man at the most suspicious time.

It is impossible within the limited space at our disposal to make a complete inventory of the correlations known to date; here are a few examples to illustrate the line of reasoning.

Cholera, for instance, has been observed all over the world in an epidemic form, but endemic foci of cholera from which epidemics spread out appear to be limited to certain regions in India. The correlations between geographical factors and the permanence of endemic cholera are low-lying lands, bodies of water rich in organic contents and salts, well sheltered from the rain and the sun.

The geographical factors which seem to be present when epidemics break out are high absolute humidity, failure of the rain, high temperature, and a congregation of susceptibles. The relationship between cholera outbreaks and

religious pilgrimages is now well established. The onset of the rain may in some places dilute the concentration of germs in bodies of water, thus apparently playing a part in bringing the epidemic to an end. But in most cases heavy rainfall, especially after a prolonged drought, may first increase the number of cases of cholera, because the rivers receive a mass of infection as a result of the downpours.

Correlation between the character of the soil and the occurrence of hookworm was first emphasized by C. W. Stiles /3/. "As soon as I entered the sandy areas uncinariasis was found. As soon as I left the sand, local foci of the infection disappeared." /Augustine, 1926,4/.

Augustine and Smillie /Augustine and Smillie, 1926, 5/ made an intensive study of the different soil types of Alabama to determine their effectiveness in producing hookworm larvae, whereas clay soils gave a widely varying yield, never reaching a percentage higher than 12%. It was, therefore, demonstrated that the disease was related more closely to the texture of the soil than to any other factor.

In further study Augustine found that no hookworm larvae could be isolated from polluted soils from December 27th to March 3rd; thus showing that the winter frosts in Alabama prevented hookworm from developing to the infective stage. Dry periods during the spring were also found to check hookworm development entirely.

"Conversely, the type of soil that favors the development of the eggs of A. duodenale is hostile to Ascaris lumbricaides. Hence an inverse proportion of infestation by both worms in males and females is usually found in Egypt, where men work in the fields and women stay around the home. In Italy, however, the women work in the fields and men go into the towns to market the

produce; hence, women bear the brunt of hookworm infestation and men get the ascarides. Cultural factors, such as less soil pollution and the wearing of shoes (as in the case of <u>A. duodenale</u>) may change the picture. On the other hand infection of the soil may be increased if an unabsorbtive subsoil makes the drainage system inadequate." /May, G. R., 1950/.

Faust in his treatise on "Human Helminthology" remarks that moisture is a result of rainfall, which is governed by winds and modified by topography. On the island of Vitileve, in the Fijis, a mountain range stops the rains from reaching the northwestern side. Hookworm infestations on the rainy side involves 90% of the native population, while on the dry side only 38% is affected. The moisture factor also affects the distribution of strongyloidosis. The free-living larvae of this parasite being very sensitive to drought, some of the helminthic infections require an intermediate host such as snails, fish, and mammals, all of which are also closely dependent on physical surroundings. As opposed to the free-living larvae of the hookworms, those of the ascarids are tougher and withstand more drought, cold, and sun. However the eggs that do not survive direct sunlight embryonate favorably on hard clay soil, while the hookworm larvae requires sandy humus.

It seems quite clear that ever since man has studied diseases, there has been a belief that a correlation existed between certain insects and diseases. An allusion is made in the Bible to the corruption of Egypt by a swarm of flies which no doubt can be interpreted as the first recorded statement of medical entomology. In 1587 de Souse /Herms, 1948, 6/ definitely stated that yaws was translated from a sick to a healthy person by the suction of flies. In 1848 Josiah C. Nott of New Orleans wrote that he thought mosquitoes produced malaria and yellow fever, a view which was shared by Beauperthuy, a contemporary French physician of the West Indies. /Nott, 1848, 7/. In 1895 Bruce

discovered the role of the tsetse fly in the sleeping sickness of cattle (Nagana) and finally in 1897 Ronald Ross announced that he had found forms of the malarial parasite in two mosquitoes /Bruce, 1895, 8/, /Ross, 1897, 9/.

At the same time a number of investigators suspected and established the role of mosquitoes in the transmission not only of malaria but also of other diseases. One of the most outstanding field experiments in epidemiology was accomplished by the U. S. Yellow Fever Commission in 1900 on the island of Cuba under the leadership of Walter Reed with the help of Carrol, Lazear and Agramonte. /Reed, 1900, 10/ At the same time L. O. Howard demonstrated that malaria in the Catskill Mountains could be controlled by using kerosene. Thus in the last years of the nineteenth century the foundation of disease control through knowledge of the contribution of geographical factors to pathological complexes was definitely laid down.

Marston Bates has made a masterly study (Bates, 1949, 11/ of the various factors of the environments as they affect the adult mosquitoes and has stressed the importance of their habits, time and distance of flight, the resting places, longevity, and seasonal distribution; also the factors influencing the sexual behavior of the various species and their food habits. The mechanism of biting, the egg development, the larval development, (which is in turn affected by temperature, light, movement of water, surface characteristics, gases dissolved water, pH, organic materials and salts), all these play an important role in the development of the larva and hence in the distribution of the diseases.

Flies, ticks, and mites are also important vectors of disease, causing such scourges as African trypanosomiasis, Rocky mountain spotted fever, and scrub typhus respectively. Their dependence upon geographical environment,

particularly their sensitivity to climatic changes, hold the key to the occurrence of the diseases mentioned.

In many cases the pathological complex is dependent upon the presence of an intermediate host. This occurs chiefly in helminthic complexes. A typical example can be found in the study of the schistosomiases. The importance of the environment has been demonstrated in Egypt, where changes in irrigation methods caused a change in the pathological picture of schistosomiasis. The intermediate host required for the development of S. haematobium is Bulinus truncatus, which is not commonly found under conditions of basin irrigation. When perennial irrigation was adopted in Southern Egypt, as it had been earlier in the Delta, S. haematobium spread to Upper Egypt. In the United States schistosome dermatitis has been studied by Jarcho and Van Burkalow, W. W. Cort, D. G. MacFarlane, F. F. Ferguson and many others. Snails of the family Planorbidae, Lymnaeidae and Physiodae serve as intermediate hosts for the schistosomes responsible for "swimmer's itch.". Geographical factors such as the nature of the lake bottom, chemical composition of the water, exposure to wind, and so on, are influential in localizing the snail and hence the disease. /Jarcho and Van Burkalow, 12/.

Man tops the list of pathogens. He is, obviously, an element in the complex and his reaction to the environment when he is healthy determines his reaction to it when he is sick. The study of the pathogen "normal man" in connection with the environment is the field of physiological climatology.

The Pathogens of Noncommunicable Diseases

If we now turn to the study of non-reversible pathogenic changes we can pursue the same line of thought. The pathogens here are represented by the various physiological functions. How do the various liver functions behave

under different climatological circumstances? How do heat, temperature, and altitude modify the creation and destruction of red cells, the excretion of urea nitrogen, the metabolism of water, the behavior of the blood electrolytes? Again we can give here only an idea of the importance of the subject. Once these factors of what might be called "anthropological physiology" are better known we may understand the geographical pattern of distribution of degenerative diseases such as goiter, hardening of the arteries, arthritis, and cancer.

The American Geographical Society is now engaged in studies of the geographical pathology of cancer. It has established contacts with key workers and observers throughout the world in order to get their cooperation in such studies. The National Cancer Institute in Bethesda, Maryland, has set up a unit of geographical pathology, which has the cooperation of pathologists, epidemiologists, statisticians, nutritionists and endocrinologists, and it is hoped to get sufficient data for the same objectives. The Council for the Co-ordination of International Congresses of Medical Sciences (CCIOMS) has organized at Oxford a symposium where these questions have been discussed. All three institutions will meet at intervals to try to co-ordinate their efforts.

Considerable variations in the prevalence of cancer by sites, types, histological definition and age groups have been noticed by workers in different countries and under various living conditions. It is reported that pulmonary cancer does not exist in Iceland and Korea, that pancreatic cancer is common in Finland, that gastric cancer is not as common in England as on the continent of Europe. It is common knowledge that cancer of the cervix is seldom observed in women who have never had sexual intercourse. But all these observations are not yet authenticated by statistical evidence.

In the United States, Dorn found that cancer was common among all age

groups of the population but that the morbidity rate for all forms of cancer and for some specific primary sites vary rather widely. He also found that females, both white and negro, were more likely than males to develop cancer, this being due to the greater susceptibility of females to cancer of the genital organs and breast. Negroes in the United States are much less likely than whites to develop cancer of the skin, but are more likely to have cancer of the genital organs. Dorn adds that the incidence rate for all forms of cancer is nearly 50% higher among whites living in the south than among those living in the north, which is explained largely by the higher incidence of skin cancer and of cancer of the buccal cavity, especially lip cancer, among persons living in the south. /Dorn, 1950, 13/. Although it is true that even in the most advanced countries statistical data only grossly approximates the prevalence of cancer, and that in most places in the world where they would be needed to support a scientific judgment statistical data on cancer distribution and demography are virtually nonexistent, presumptive evidence of the influence of geographical factors on the occurrence is present in sufficient degree to justify further studies in this matter. The facts as gathered last year at the Oxford Symposium appear to be:

1. Primary cancer of the liver is relatively more common in Africa, Indo-China, India, Malaya, Indonesia, and the Philippine Islands than anywhere else in the world.

2. Cancer of the cervix of the uterus is relatively uncommon in Jewish women.

3. Cancer of the stomach is relatively infrequent in Javanese, African negroes, and the indigenous people of French North Africa.

4. Cancer of the base of the tongue is relatively frequent in certain

communities in India.

5. Cancer of the scalp is frequent in inhabitants of French North Africa; of the skin of the trunk in the inhabitants of India, of the scalp and skin of the legs in African negroes and Indonesians.

6. Relatively large numbers of cancers of the pancreas have been reported from the Mulago Hospital at Kampala, Uganda.

7. In Indonesia, India, and Indochina an unusual number of malignant tumors of the cervical lymph nodes have been reported. /Oxford Symposium, 1950 14/.

Although it is too soon to state with finality that certain factors, exclusive of others, are instrumental in governing the occurrence of cancer cases, there are enough indications to show which of these factors may be of particular importance.

a) Infestation by parasites. The carcinogenetic properties of certain helminths were reported long ago. Kouwenaar /Oxford Symposium, 1950, 15/ reports that in Indonesia and India scars of yaws seem to be correlated with skin cancer in significant numbers. Whenever S. haematobium is common in Egypt, Tunesia, Morocco, cancer of the bladder seems to be prevalent.

b) Common usage of irritant substances seems to have an influence on certain forms of cancer. These substances may be connected with certain occupations; (for example, scrotal cancer was common among chimney sweeps) others are correlated with local usages and culture. There seems to be a correlation between the occurrence of oral cancer and the chewing of betel nut; according to Joyeux /Oxford Symposium, 1950/ this is found in IndoChina only when the betel nut is taken with lime, mainly provided by burnt sea shells. Steward /Oxford Symposium, 1950/ remarks that in certain parts of the United

States physicians have been impressed by the development of cancer in the parts of the mouth where tobacco chewers keep their cud. Furthermore there is a correlation between heavy persistent smoking and cancer of the lungs.

c) Nutrition seems also to have an important action on the occurrence of cancer, although how is not yet clear. There seems to be in certain types of starvation an increase in estrogenic hormones, which may in turn result in gynecomastia and also in precancerous or cancerous conditions. Bonne, van Veen and Sutoma /1941, 16/ produced primary cancer of the liver in rats submitted to a diet of polished rice, thiamin, cod liver oil, carrots and butter yellow in olive or coconut oil. However, it must be kept in mind that no definite proof that these factors have any relevance can be established in humans as long as studies are not made in various countries on comparable populations. There is no doubt that in countries where life expectancy at birth does not exceed 35 to 40 years, the cancer age groups are practically nonexistant.

American Contributions

The condensed inventory of our knowledge in the field of medical geography confirms that none of the discoveries described was made by scientists who considered themselves medical geographers. Our stockpile of medicogeographical information is accumulated from a number of allied sciences: bacteriology, biology, entomology, and others. Various institutions in America have promoted research in these fields, and have thereby contributed to our knowledge of medical geography. Among the most important are the Rockefeller Foundation, the United States Public Health Service, the United States Army and the United States Navy; these active organizations have gathered an impressive body of medical intelligence basic to the study of medical geography

The fields in which American research has made history are hookworm, yellow fever and malaria.

American interest in hookworm diseases started after the Spanish-American war when Ashford examined the faces of patients in Puerto Rico for the larvae of A. duodenale and found them in great numbers. /Ashford, 1904, 17/. Following Ashford's paper, C. W. Stiles, of the United States Department of Agriculture, described in 1902 a new indigenous species of ankylostoma (N. Americanus), which he claimed to be widespread in the United States. /C. W. Stiles, 1903, 3/. In 1905 a hookworm campaign on a limited scale was begun in the southern states by the United States Public Health Service. Finally the Rockefeller Sanitary Commission for the Eradication of Hookworm Diseases was organised on October 26, 1909, and was endowed with a gift of $5,000,000 by Mr. John D. Rockefeller, Sr.

American interest in yellow fever, perhaps the most dreadful scourge in the Western Hemisphere, was awakened early. The crowning event was the sending of the Walter Reed Commission to Havana in 1900 to protect the lives of American soldiers, who were dying in great numbers of the dreaded disease. Their discovery of the rolé of A. aegypti (then called Culex fasciatus) in the transmission of the disease laid the groundwork for several control campaigns which were to have dramatic repercussions on the health of mankind. Most famous among these were the Havana campaign, the New Orleans campaign, and the Panama Canal Zone campaign.

The Havana, based on the natural history of the mosquito, was entrusted to Colonel Gorgas, who succeeded in complete eradication of yellow fever from Havana. Similar successful results were obtained in New Orleans in 1905.

The Panama Canal Zone Campaign demonstrated that a knowledge of the

domestic characteristics of Aedes aegypti - which may breed in houses in the smallest collections of water left in tubs, barrels, kerosene tins, and bottles or in crab holes, tree cavities, and roadside ditches - were essential to the eradication of the disease. On this knowledge was based the work of the Yellow Fever Service of the Rockefeller Foundation's International Health Division and what Soper has described as the golden age of achievement in the eradication of yellow fever was made possible.

By 1925 it was believed that the western hemisphere had been freed of the yellow fever danger, but in 1926 a new outbreak occurred in northeastern Brazil, and the way was open for new research which eventually brought about the discovery of Jungle yellow fever. The Rockefeller Foundation concluded in the end of 1949 its 27 years of cooperation with the Yellow Fever Control Program of Brazil. "A 15 year investigation of the geographical distribution of immunity to yellow fever among the primates of Brazil has established the fact that jungle yellow fever has prevailed practically everywhere in Brazil during the past decade and a half." / Rockefeller Foundation, 1949, 18/

Malaria Control

Since 1916 the International Health Division of the Rockefeller Foundation has assisted various countries in anti-malaria schemes, working hand in hand with the respective governments, notably in Argentina, Puerto Rico, Nicaragua and Brazil. In 1924 and 1925 a similar helping hand was held out to Italy, Poland, Palestine and the Philippines.

The Anti-gambiae Campaign jointly developed by the Rockefeller Foundation and the Brazilian Government is a good example of applied medical geography and is a monumental contribution to the science. The arrival of Anopheles gambiae in Brazil in 1930 was followed by serious outbreaks of

malaria in 1930 and 1931. "The first organised campaign in 1931 apparently resulted in the eradication of Anopheles gambiae from Natal, its port of entry, but not until after it had found a footing in the interior of Rio Grande de Norte." /Soper and Wilson, 1943/ After a quiescent period, terrific outbreaks of malaria, with high mortality rates, occurred in 1938. To meet this emergency the malaria service of the northeast was organized, supported jointly by the Brazilian Ministry of Health and the Rockefeller Foundation. This expedition showed to what extent biological information and cartographic and geographical techniques could be combined to achieve success.

Anopheles gambiae is one of the most dangerous malaria vectors because of its almost complete affinity for human blood. The breeding requirements of gambiae had first to be ascertained. They were found to be small shallow ground pools, either clear or muddy, free of vegetation, exposed to sunlight, in proximity to human dwellings where the climate is characterized by absence of frost and a range of temperature of less than 40°F. /Soper and Wilson, 1943, 19/. One of the first activities of the new anti-malaria service was to establish a cartographic unit, the duty of which was to map the operative regions and keep close track of the progress and retreat of the enemy. Air maps of certain sections were made and the necessary ground work, developing and printing of the photographs, and preparation of the final maps were done on the spot. The technique of eradication was established after a close study of the microclimates which govern the life of the vector. It was demonstrated that general species eradication was feasible and at the same time more effective than simple anti-malarial measures.

American researchers have actively plowed other fields of medical geography.

Pellagra. In 1913 the United States Bureau of Public Health started an investigation into the cause of pellagra. J. Goldberg, head of the mission, demonstrated the correlation between the disease and dietetic and standard of living factors which paved the way for the present day conception of the disease.

Fluorine and Dental Carries. Although a number of references to the relationship between fluorine contents of water and dental carries can be found in the literature of the last quarter of the nineteenth century, systematic study and exploration of this correlation dates from the work of G. V. Black and F. S. McKay, /Black and McKay, 1916, 20/. These studies have been continued chiefly by officers of the United States Public Health Service, among whom the names of H. Trendley Dean, F. A. Arnold, and P. Jay Elvoa must be cited. More recently A. Van Burkalow /Van Burkalow, 1946, 21/ of the American Geographical Society published a series of maps showing the distribution of fluorine in United States water supplies. /For complete bibliography, see Dean and Kitchin, 22/.

Tularemia. Tularemia has also been chiefly studied in the United States G. W. McCoy discovered in a ground squirrel, (Citellus beecheyi), a disease characterized by lesions resembling those of plague. Later, in Tulare County, California, G. W. McCoy and C. W. Chapin described the causative organism and named the bacterium "Tularensae." /McCoy and Chapin, 23/. The first infection in man was recognized by Wherry and Lamb, in 1914. Further important work on the numerous reservoirs found in the American fauna and the various vectors such as the deerfly, (Chrysopsviscalis); the rabbit louse, (haemodipus ventricosus), and a number of ticks acting both as reservoirs and vectors, has been accomplished by officers of the United States Public Health Service.

Rickettsial diseases. Rickettsial diseases and the medical geography of some of them have been a field for important American Studies. The United States Public Health Service has established a laboratory in Montana where important work has been done on ticks known to be natural vectors of Rocky Mountain spotted fever. In the United States, Rocky Mountain spotted fever has been reported from 43 out of the 48 states: Maine, Vermont, Connecticut, Rhode Island, and Michigan are the exceptions. The geography of the various carrier ticks has been established, the most important being D. Andersoni, the Rocky Mountain wood tick; D. variabilis, A. americanum and H. leprosis palustris, the rabbit tick. Their geographical occurrence has been studied by such workers as Cooley, Kohls, Breman, Bishopp, Trembley, Parker and Steinhaus. /Kohls, 1943, 24/. Rickettsial pox has been described for the first time in New York City by Huebner, Stamp, and Armstrong. It is carried by a mite (A. sanguineus) the locale of which seems to be mainly big cities, such as New York, Boston, Philadelphia, Indianapolis, Tucson, and others.

Problems and Methods

Research problems of the medical geographer

As we have shown in the previous pages the individual stones which have been brought together to build up the existing edifice of medical geography have been gathered from various branches of the medical sciences. Each of these component sciences has its own methodology, which might perhaps lend itself to the study of medical geography. However, it is not our aim in this article to break down the subject into its component parts; but on the contrary to make a constructive synthesis. Does there exist such a thing as a method proper to the systematic acquisition of knowledge in medical geography? How does one think in medical geography and how does one acquire knowledge?

The first problem is to find a means whereby accurate data can be collected. Unfortunately, our knowledge of distribution is now chiefly based on reports made by various individual physicians to governmental health agencies, on reports of hospitals, on published papers dealing with individual cases, and on a small number of field surveys.

Results of these methods give at best an incomplete picture of the disease occurrence and no picture at all of diseases which may have occurred in the past but were not reported. The vast majority of pathological cases are never scientifically observed. Some are observed, but not recognized. Some are recognized but not recorded, while fewer still are both accurately diagnosed and efficiently reported.

In awareness of this condition, several attempts have been made by the United States Public Health Service workers to investigate on a broader basis some sections of the United States population. A. L. Chapman has recommended multiple screening - which consists of performing a battery of tests at the same time on a given section of the population - drawing attention to the hygenic value and low cost of the method. These tests reveal incipient or concealed diseases. The program is designed to reduce the cost of public health expenditures, not with the research of geographical correlation in mind.

Harold F. Dorn has conducted a master survey of cancer in ten cities of the United States in order to build up a picture of cancer occurrence; also, under the auspices of the United States Public Health Service, a national health survey has been undertaken to discover prevalent diseases among large numbers of families. A description of this survey has been made by G. St. John Perrott and collaborators.

For the purposes of medical geography the recording of actual diseases is important and forms a worthwhile contribution; but in addition a method of detecting the traces left in the individual by non-clinical forms of diseases - the footprints of diseases - should be developed. Not until such information is available can we build up an accurate picture of the prevalence of diseases in a given region and proceed to the study of geographical correlations.

To this end the American Geographical Society has recommended a regional study where data on the prevalence of certain diseases can be brought to light. The Society's method is based on the principle of sample studies of populations. These samples must be carefully chosen so as to be representative of the normal types and of the deviation types. Details of the statistical problem cannot be given here. Briefly, it is estimated that the study of a 3,000 unit sample would give information on 1,000,000 people for the diseases under consideration. The margin of error would be small if the prevalence of the disease is great.

In order to make the technique as simple as possible the person submitted to the studies would be directed to five different desks: namely, 1) a general information desk, 2) a clinical desk, 3) a blood desk, 4) an X-ray desk, 5) a stool center. Thus, information relating to some twenty of the most important diseases the subject has been exposed to would be revealed, the populated area over which such diseases extend would be made visible, and the futher study of correlation with geographical environment would acquire significance.[7] The results of these check-ups could then be mapped for study against geographical factors.

Presentation of data on maps.

The main purpose of a medical map is to locate the pathological phenomenon and then to establish the geographical correlations resulting from this

localization. In these pages we cannot discuss all the aspects of the problem. this will be done extensively in the report presented by the Commission on Medical Geography of the International Geographical Union before the Washington Congress in 1952. But let us illustrate our point by giving an example of a census type of map, the Society's map of poliomyalitis /May, 1950, 25/.

This map shows the occurrence of the phenomenon with the rates qualifying its intensity and the age groups most likely to be attacked for every place in the world where data could be assembled. There has been no effort at correlation; it is a census map only. It indicates how difficult is the task of entering, as would Jusatz, all factors capable of influencing the epidemiology of a disease. A certain amount of mental effort is required on the part of the reader to study what possible geographical factors can affect or govern the picture of occurrence submitted.

On the cholera map, published in April 1951, an attempt is made to show well-established correlations. "The epidemiology of cholera raises several problems, which from the geographer's point of view can be summarized thus. Under certain circumstances, some of which are known and others not, the disease breaks out in epidemic form. Epidemic outbreaks have occurred in different climates, though some parts of the world have remained completely uneffected. Under other circumstances, some of which are understood and others not, cholera remains quiescent, showing its presence by continuous small numbers of cases, which at certain times and during certain seasons become epidemics of various morbidities and mortalities. This type of cholera is confined to certain districts of India. For these reasons we distinguish the study of epidemic or occasional cholera from that of endemic or permanent cholera. Occasional cholera is linked to factors of human geography. It

correlates with the density of population, permanent or transient. When large numbers of susceptibles are gathered together, as on pilgrimages, those coming from cholera-infected areas bring the disease with them, spreading it everywhere on the way. They contaminate their fellow worshipers, who in turn spread the pestilence as they return to their homelands.

"As one has to eat or drink the germ of the disease to become contaminated, the cultural and religious habits of human groups, the social customs and amenities, influence to a great extent its areal distribution and morbidity.

"The disease is also linked to factors of economic geography, spreading through the inhabited world along the routes of commerce, by caravans, ship lines, or railroads, at a speed that is sometimes, but not always, proportionate to that of the carrier. (Compare the slow advance by caravan of the first three pandemics with the rapid advance by steamship and rail of the fourth).

"The disease is also linked to factors of physical geography. Epidemics break out in hot, humid weather and frequently die out in winter. In some places an epidemic ends with the onset of the rainy season; in others the rains help spread the pollution of water bodies. On the east coast of Africa up to the end of the last century, cholera, when it occurred, coincided with the arrival of the northeast monsoon, which brought dhows from India.

"Permanent cholera seems to be found well below the 500-meter line in India, where the population is dense and temperature and humidity are always high. In these places the germ remains quiescent either in man or in nature during certain seasons if it can find sheltered bodies of water rich in organic content and in salts. We have tried to show these various features on several maps." /May, 1951, 26/:

Program and Forecast

Having thus briefly reviewed the field of medical geography, let us outline the program for future research as we conceive it. Of paramount importance is the problem of information. This should pertain to the health as well as to the diseases of man. A good knowledge of the physiological anthropology (that is, of the normal physiological character) of the population under study should be acquired. It is indispensible to the sound understanding of the occurrence of pathology. We have to know what the normal man is before we can decide when he is sick. This detailed information, which is the basis of medical geography, will be very hard to get, but we have suggested in the preceding pages how this might be achieved. The study of correlations may well begin thereafter.

Some geographical factors do not lend themselves to measurment, only to description. A comprehensive picture of the geographic environment can be made against which the occurrence of disease can be studied. The first step would be analytical, breaking down the most prevalent pathological phenomena into their pathogenic complexes and relating each to the geographical data. The second step would be to build up a composite picture resulting, it is hoped, in a more profound understanding of the "whys" behind the occurrence of diseases.

Some of these correlations might be studied in the laboratory by entomological and bacteriological techniques. The behavior of certain pathological complexes or physiological functions in the laboratory under artificial climates is a method with a recent past, and, we hope, a very great future.

At the end of this expose it may not be too presumptuous to outline a

working hypothesis and to risk a prediction. It is entirely possible that once a global picture of the proportionate prevalence of certain pathological phenomena is outlined, we shall discover that the same pathological phenomena always occur in the same places. It is also possible that we shall then see that the occurrence of certain diseases precludes the occurrence of others. For instance, this would be the case in a country where cow pox would be prevalent; no small pox would ever occur. In the same line of thought it may well appear that the food produced by certain soils, the diets based on these foods, the cultural characteristics which have contributed to the diets, allow or forbid the prevalence of certain noncommunicable degenerative diseases, such as goiter, hardening of the arteries and cancer. This idea that pathological phenomena occur in a pattern that we might venture to call a "social pattern" - as men, plants, and animals live in societies - may be a hypothesis on which the studies of medical geography may well rest.

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ZOOGEOGRAPHY

This section was not written for the preliminary copy of volume.

(Preston E. James, Chairman, Committee on American Geography)

PLANT GEOGRAPHY

Introduction

The study of the geographical distribution of plants is generally referred to as plant geography although the terms phytogeography or geobotany are also sometimes used. Three sets of processes working simultaneously, control this distribution, namely: (1) those residing within the organism, which may be termed genetical; (2) those residing in the environment, called ecological, and (3) those which work through long periods of time and account at least in part for evolutionary trends. It cannot be over-emphasized that these processes must be considered together as a single complex and that it would be incorrect to explain the geographical distribution of biota on the basis of only a part of this complex.

The grouping of individual plants into plant communities is also a fundamental object of investigation in plant geography and is now being developed as phytosociology or the study of vegetation. This is a particularly promising field of study because of its numerous practical applications. Finally, there is another aspect, especially dear to geographers: the cartographic representation of biogeographical data, especially of vegetation.

So far, the role of plant geography in American geography has been extremely modest. Leading geographers in this country have repeatedly demanded that more emphasis be placed on phytogeography but the results have been negligible. In biogeographical research, Europe is also ahead of the United States with regard to journals and research institutes. The beginnings of American plant geography may not appear to have been very promising compared with European achievements. However, throughout the 20th century

there have been American scientists who have made significant contributions to phytogeographical research and for some decades these contributions have been equal to the European ones in caliber and significance.

Floristic Plant Geography

For many botanists the geographical distribution of species and other taxonomic units is synonymous with plant geography, and in botanical circles everywhere emphasis has been placed on this aspect of phytogeography, whereas the attention of geographers to this branch of phytogeography has been negligible. Geographers have always felt that floristic plant geography is less intimately related to their work than the study of vegetation. But it is quite clear that an exhaustive study of vegetation is impossible without considering the results of floristic geobotany.

In dealing with the area occupied by one species one becomes inevitably involved in a series of problems which all stem from the several aspects of phytogeography. The historical development of the area through geological ages is as important to consider as the historical development of the species itself; obviously, the present environment exerts a strong influence also, and we therefore come to see in the present distribution of a species the integration of a large number of factors working simultaneously through long periods of time, producing changes which forever continue.

Descriptive work is relatively free from controversy in contrast to the dynamic features of geobotany which link the distributional aspects of plants to both the evolution of the occupied area and to the evolution of the species. Just as Alfred Wegener created an uproar in geology, geophysics, geography and biology by theorizing on continental drift and thereby stimulating a vast number of fruitful researches, so M. L. Fernald on a more modest

scale produced an upheaval with the introduction of his theory on conservative versus aggressive species, and as a sort of corrollary, his nunatak theory. The latter, without doubt, is better known among American geographers. Fernald boldly proclaimed that the North American extent of the Pleistocene glaciation had been overestimated and that many areas protruded through the ice sheet serving as refuges for a host of plants. Such islands in a glacial ice sheet are called nunataks, an eskimo term. Much evidence was produced in support of this theory or to disprove it, and the evidence was indeed sound and yet contradictory. Plants seemed to have survived in areas which were certainly glaciated, although it was not always clear which particular advance of the ice sheet was involved. In spite of the brilliant demonstrations of Fr. Marie-Victorin (1938) which seemed to disprove much of the theory, Fernald staunchly upheld it unto his death. There can be no doubt that the peculiar distribution of some species in eastern North America is little related to the glacial processes, if at all, and many of Marie-Victorin's observations are irrefutable. On the other hand, Fernald's ideas did lead to the re-examination of many broader generalizations and it is now clear that nunataks must have been more common than was realized earlier. Present nunataks in Greenland bear considerable plant life and it may be assumed that this was also true in Pleistocene times. Even in the unlikely event that the nunatak theory should eventually be discarded entirely, it has resulted in much valuable research which would have remained undone without Fernald's provocative speculations.

An altogether different approach to historical problems was used by Hugh Raup (1947) whose investigations in northwestern Canada tested Hulten's (1937) theories of equiformal progressive areas of present plant species. His

positive and very stimulating results might well have been much deeper and more far-reaching, had more detailed data on the geographical distribution of species been at his disposal. His work clearly points up the need for accurate distribution maps if this research is to be continued and refined.

In the meantime the geographical distribution of species become an object of study for geneticists. The outstanding works of Clausen, Keck, and Hiesey (1940), and Camp (1941, 1947), are blazing a new trail to phytogeography. The genetic methods permit one to study the evolution and relationships of species and thus follow the development of their present areas by linking the evolving areas with the evolving species. In this manner it becomes possible to trace an evolving species through both time and space and to find an explanation for distributional patterns which would otherwise remain baffling.

Perhaps it was Stanley Cain among all geobotanists who rendered geographers the greatest service, for among his many works is one of the greatest significance for geographical circles, namely, his Foundations of Plant Geography (Cain, 1944). Characteristically the title contains "plant geography" although the book is limited almost entirely to floristic plant geography, whereas the ecological and sociological branches are barely touched. But it is precisely the floristic aspects of plant geography that geographers know least about and Cain supplied them with a detailed and comprehensive summary of the latest developments. He presents the basic features which affect the distribution of species through time and space; hence his strong section on paleoecology; hence also his excellent chapters on areography which deal with the areas that species occupy and as this is an especially important aspect of plant geography which had not been adequately presented in America, geographers welcome this part of Cain's book above all. Cain closes his book

with two strong sections on the relation between plant geography and genetics. As most geographers have little or no background in genetics, and in view of the growing significance of genetical work in phytogeography, Cain's contribution is a very real one. Cain's Foundation of Plant Geography, dealing mostly with floristic geobotany, should now be matched by a similar book on vegetation. Such two books, combined with one of the more outstanding ecological texts, would be an excellent basis on which to erect a series of much needed university courses.

A most significant development is taking place at the present time with the application of the carbon-14 method. The decay of radioactive carbon-14, especially in wood, can be used to establish the age of the wood, and in Pleistocene and post-Pleistocene times enough wood has been deposited to permit numerous studies in many places. Correlating the results of such investigations reveals that in North America the length of the period between the last glaciation and the present may have to be revised considerably. The effect of such results on our theories of species evolution and migration may be far-reaching and plant geographers everywhere must follow this development with serious attention.

Ecological Plant Geography

The ecological viewpoint is fundamentally part of both floristic and vegetational plant geography, but the ecologists have developed their field in such relative isolation that it is useful to discuss the subject separately.

The science of phytogeography must always consider ecology one of its very cornerstones, but ecology is nevertheless only one in a series of such stones in a large structure. Also, Americans did not invent dynamic ecology as most of them seem to feel. In fact, this concept is as old as the science

of plant geography itself, for it was Willdenew (1792), the forerunner of Humboldt, who conceived of the dynamic aspects of vegetation.

These early and basic thoughts were ignored in this country, but when American ecologists began to assert themselves with the advent of the 20th century, they soon made up for lost time. They adopted much of the thinking of the European ecologists, notably of Warming and Schimper, and established their own schools of thought..

There can be no doubt that American ecologists have made important contributions to their science. They have published a vast number of books, monographs and scientific papers, and in Ecology and the Ecological Monographs they possess two journals devoted to ecological research. For decades they promoted ecology, neglecting every other aspect of phytogeography, and the amount of detail that has been accumulated during the past five decades is truly impressive.

At the end of the 19th century, Merriam (1898) proposed the establishment of "life zones." Accordingly a continent is divided into climatic zones or belts characterized by certain biota. This was a fertile idea which found wide acceptance. A great refinement of this idea lies in Hopkins' (1938) use of phenological data to establish the zones but very few ecologists have ever availed themselves of the possibilities which Hopkins offered. The vast majority of ecologists in this country were and still are almost completely

under the spell of the founders of American ecology whose theories are accepted like gospels. That such a development stifles growth and originality is almost inevitable.

Early American ecology evolved under the leaderships of Clements and Cowles, and was stimulated by Shreve, the most geographically-minded of American ecologists (vice president of the Association of American Geographers, 1940; president of the Association of Pacific Coast Geographers, 1941-42). Their innumerable followers faithfully continued in the established grooves, improving the techniques but adding little else. Clements' dynamic approach to ecology proved immensely stimulating. He reintroduced the concept of succession, developed and refined it, and classified the vegetation on the basis of succession (Clements, 1916). Quite logically, his ecological investigations led to the concept of indicators which he greatly developed (Clements, 1920). Later on, he became interested in relicts and studied vegetation from this point of view (Clements, 1934). Clements introduced early the concept of climax vegetation, in which a plant community has passed through all phases of its succession and reached a state of equilibrium with the climate of the region. But he never accepted the possibility of an edaphic climax and apparently was quite ignorant of environmental conditions in high or low latitudes. His ideas of the climax concept were tested throughout the world. It is becoming increasingly evident that the climax is often too elusive to be useful and that the succession leading to it may be lacking. Raup's observations in the Far North led to the conclusion that succession as developed by Clements, requires a certain stability of the environment through the centuries, so that the changes can proceed properly. The manner in which lakes gradually fall victim to an ever-increasing vegetation, or the vegetational changes under the influence of the erosional cycle, all require a certain

stability of conditions. But Raup finds that this stability is often wanting, and that Clementsian theories are less useful in higher latitudes. He came to similar conclusions in the broadleaf evergreen forests of tropical lowlands, while Shreve (1942) found that the theory of succession, as usually formulated, does not apply to the desert. And yet, there can be no question about the enormous stimulus which ecology all over the globe received from Clements' vivid imagination.

Cowles in the meantime developed physiographic ecology, observing the inevitable changes of the vegetation as the land forms undergo their erosional cycles. The basic ideas of dynamic ecology had been imported from Europe where they had never been applied. But when W. M. Davis developed his ideas on erosional cycles, it was Cowles who recognized the correlation between the dynamics of landforms and those of vegetation and put wheels under the study of ecological plant geography. In the dynamic sense that has become so characteristic of American ecology.

The environmental factors became fixed notions in the minds of the ecologists and all efforts were bent on grasping the meaning of each individual factor. One learned to speak of the climatic, edaphic or biotic environment and studied climate, soil and biota in isolation. As each of these factors is a whole complex of factors which can be investigated separately, the research possibilities grew in number to vast dimensions.

The attempts to explain the distribution of vegetation on the basis of a single environmental factor, climate, reached their culmination in the painstaking researches of Livingston and Shreve (1921). The amount of thought and energy spent on this monumental work has never been matched in any similar or related project, and at the end, the authors had the rare courage to

recognize that such attempts must need be futile; but so far, the great lesson which they taught has been ignored by nearly everybody.

Ecology was eventually divided into autecology which deals with the environmental relations of individual plants, and synecology which studies the environmental relations of plant communities. Our autecological knowledge was recently summarized by Daubenmire (1947) while Oosting (1948) did a similar service to synecology. Simultaneously there goes on a large number of researches which deal with some limited aspect of either autecology or synecology and all the results only form an ever bulkier mass of data. It seems that plant ecology has somehow reached its growth limits. It is proving its usefulness in applied fields (agronomy, forestry, range research, entomology, etc.) but it has distinct theoretical limitations and new ideas are extremely rare. One analysis follows another but nobody erects a new edifice with all these building blocks. Ultimately, ecology is forced to regenerate itself or be dissolved in physiology, pedology or climatology. The bright sparks emanating from the work of Clements, Cowles, or Shreve are not kept aglow by their successors and the present trend forces one to the conclusion that ecology has now made its chief contributions and must surrender the future to the still youthful and much more promising study of plant sociology.

Plant Sociology: The Study of Vegetation

In the minds of most American geographers the study of plant geography has come to be more or less synonymous with the study of vegetation. This is as narrow an approach as that of the botanist who sees little more in plant geography than the geographical distribution of species. But the viewpoint of the geographer is more acceptable than it appears at first sight. For the study of vegetation implies not only the investigation of most significant

aspect of the landscape with which the geographer deals, it implies also a comprehensiveness of approach that is not equalled in any other branch of phytogeography. Vegetation consists of plant communities and these in turn, consist of individual species and life forms which live together. In cities the vegetation has been removed altogether but even the largest cities are no more than tiny dots on the globe, and outside the cities (and sometimes even within) the vegetation spreads its meaningful cover over the continents and islands and extends far out into the sea. No feature of the landscape is more revealing, nothing can help an exploring geographer to appreciate the character of a region as well as the vegetation. Hence, he speaks about vegetation when he thinks of plant geography and in his textbooks (if he refers to plant geography at all) he rarely mentions the floristic aspects as outlined above; he limits himself almost exclusively to vegetation.

But as a science, plant geography is young and so is American geography as a whole. No wonder then that in spite of repeated pleas, geographers in this country have done very little indeed to promote a branch of knowledge the importance of which they themselves have stressed so often.

The significance of vegetation to geographers rests not only on esthetic qualities which have been ignored almost completely and quite unjustly so, but above all on its very far-reaching indicator value. Species have long been known for their use as indicators, but in most cases they do not compare with plant communities. For the area of a species is determined by different controls in different regions and while a species may well dominate a community and justly be called the index species of that community, this same species may and usually does occur elsewhere, too, often far removed from the formation in which it finds its optimum conditions of growth and survival. On the other

hand, a plant community with its characteristic floristic composition and particular sets of life forms is not only a sure indicator of the coarser environmental and historical aspects of the landscapes, but it unerringly points out the more subtle and hidden characteristics as well.

As soon as a plant community is recognized as a separate and integrated entity, it becomes evident that studies of individual species cannot simply be transferred to the plant community because one deals here with a unit of an altogether different character. Unfortunately this has not always been understood by American students of vegetation, and it is here that much progress may be expected in the coming decades.

Thanks to innumerable European studies, it is well known, though not always realized in America, that a thorough phytosociological knowledge has a great practical value. In forestry, it is leading toward a complete re-evaluation of the conventional outlook. In pasture management, in land evaluation especially for land use, in industrial and numerous other problems, the study of plant communities is proving its worth. Already there is such a specialist as a "Vegetationist" whose main activity it is to advise commercial and governmental organizations with regard to the management of plant communities. This is an immensely promising field of investigation which can be profitably expanded by enterprising and imaginative students of vegetation.

In America the study of vegetation is nearly as old as the study of phytogeography itself. One of the first significant publications was "The Phytogeography of Nebraska" (Pound and Clements, 1898) the last part of which is largely a vegetational study. Since then there has been a steady stream of papers and monographs of vegetational studies, mostly with a strong ecological slant, scattered throughout the botanical literature.

In the meantime the historical approach to the study of vegetation increased in popularity. Many geographers know the work of Hugh Raup (1937) on New England. E. L. Braun (1928 , 1936, 1937) wrote a series of papers on the historical development of some of the forests from the Appalachian Mountains in the east to Ohio in the west. Others worked simultaneously, and while many data in these papers are based on fossil remains, a great stimulus came with the introduction of pollen analysis. This is a method largely developed in Sweden and is used most successfully in areas of Pleistocene glaciation. The principle is simple: with the discovery that pollen grains of many species are preserved in bogs (under exclusion of oxygen), it became largely a matter of taking cores from bog deposits and observing the pollen accumulations in the various layers. Presumably the pollen comes from plants in the vicinity of the bog and is blown in by the wind. The sources of error are considerable; but by correlating a very large number of tests it becomes possible to obtain a rather accurate picture of the vegetation at various times, at least with regard to the prevailing tree genera. This does not only permit conclusions as to the past composition of the vegetation but gives direct clues to the past migration of plants and indirect ones to the climatology of the past. Hansen has done much work of this sort and his monograph on the vegetation of the Pacific Northwest (Hansen, 1947) is a fine example of what can be done. Potzger, Sears, Cane, and many others have carried on similar researches in the eastern part of the United States.

The need for an over-all presentation of the vegetation of large areas was recognized early in Europe and at the behest of a German publishing firm, Harshberger (1911) wrote his massive treatise on the vegetation of North America. This great piece of work has been criticized by many but it is much

more realistic than some of the reviewers would indicate, especially as one can get a rather true impression of the vegetation as it occurs in the many parts of this continent and without those speculations about what the vegetation ought to be on the basis of some successional scheme as one finds them so often in later papers. Certainly, no one has been able so far to produce a superior work covering the whole continent.

A classic of American plant geography was the Vegetational History of the Middle West by Gleason (1922) in which he foretold the story that pollen analysis is laboriously working out. Also, Gleason's individualistic association hypothesis is an original approach and a rebellion against both Clements and Braun-Blanquet.

Recently Braun (1950) published a comprehensive treatment of the deciduous forests of eastern North America. Although more limited in scope than Harshberger's work, Braun covers nevertheless a vast area and incorporates the ideas of the last four decades. It is books like this one by Braun that are so valuable to the geographer.

There seems to be neither the time nor the inclination in American geographical circles to obtain a thorough botanical background. This is unfortunate because students are deprived of their chances to acquire that breadth of training which is so valuable, if not altogether necessary in any biographical research. This is one of the major reasons why so few geographers devote their time to a field which fairly begs to be explored. The lack of background places a large number of the more detailed vegetational studies beyond the grasp of the average geographer, and a book like that by Braun as well as that by Cain is then doubly valuable. Here we find in bold strokes a picture of the vegetation of a very large territory, both in its present setting

and in its historical development.

On a much smaller scale, many others also have made valuable contributions which are readily appreciated by geographers; they are too numerous to be listed here. Thus work goes forward on all scales and on different avenues of approach, and yet a clear direction seems lacking. Only recently Egler (1940, 1942, 1947, ms.) succeeded in penetrating through the enormous amount of material that has been accumulated and began to question the very concepts with which American students of vegetation had become so accustomed to work. The philosophic depth of his work has placed Egler among the foremost thinkers among the American phytosociologists. Simultaneously with his theoretical work he carries on important experiments; for example, his semi-natural self-perpetuating plant communities have become valuable to hydro-electric power companies. If American phytosociology while plodding forward nevertheless is somewhat in a rut, it may well be Egler who will blow up the next bridge and thus force a reconsideration of the course of advance with a re-evaluation of criteria, methods and goals.

Vegetation Maps

The map is the geographer's most important tool. It is not surprising, therefore, that vegetation maps assume special significance for the geographers who wish to do phytogeographical research or apply its results. However, what is natural for geographers is not necessarily obvious to botanists; as most phytogeographical investigations are made by botanists, the vegetation maps have often been sadly neglected, and it is common enough to find regional descriptions of vegetation without a vegetation map. The practice of mapping vegetation scientifically is essentially as old as our own century, but

progress in this country has lagged far behind European achievements. The United States has not yet seen fit to establish an agency to map vegetation, such as the Service de la Carte de Végétation de la France of the French, or the Germans' Zentralstelle für Vegetations-Kartierung, or the Swiss "Pflanzengeographische Kommission." There is in this country nothing to match or even to approach the superb maps of France (1:1,000,000 & 1:200,000) by Henri Gaussen (1945, 1948); of Germany (1:1,000,000) by Kurt Hueck (1943); and of Switzerland by Schmid (1948). In style and detail, in method and comprehensiveness, the European maps continue to be greatly superior to our own performance, and it will take much timebefore we can successfully emulate the Old World masterpieces.

However, America is by no means without its distinctive achievements. At the beginning of the second decade of this century, enough material had accumulated to permit Harshberger (1911) to prepare a vegetation map of North America (1:40,000,000). It cannot be overlooked here that Europeans had preceded Harshberger by several years, and especially Schimper's map (1898) of the world had become widely known.

But progress was slow. Shreve (1917) presented his new vegetation map of the United States to the readers of the Geographical Review. Although of small scale and highly generalized, this map revealed an unusually clear insight into the nature and the problems of American vegetation.

Curiously enough, there followed a period of several years during which not a single significant vegetation map was published. Then two maps appeared, both of large areas and on a similar scale, and these two maps continue to be among the most noteworthy American achievement so far. These are the maps of Africa (1:10,000,000) and Shantz (1923) and of the United States (1:8,000,000)

by Shantz and Zon (1924). This performance of accuracy and clarity was all the more remarkable because until then source material was relatively sketchy and the number of large-scale base maps was either very small or, in many instances, it was nil. Although these two maps are now nearly three decades old, American geographers are, generally speaking, more familiar with them than with any other vegetation maps that have been published since, regardless of region, scale, or quality.

It seems that this double-barrelled explosion after a hiatus of six years shocked interested parties into action, for ever since the publication of the maps of Africa and the United States there has been forthcoming a stream of vegetation maps. This welcome development certainly deserves the support of everyone interested in any aspect of biography. But this development must also move along sound scientific lines if the maps are to be of lasting value. In this respect, many of the vegetation maps published during the past quarter of a century show symptoms which cause concern. A closer inspection of the various maps reveals that a variety of unwelcome aspects have been permitted to creep in which, if continued, will be a hindrance rather than a help in developing vegetation maps of superior quality.

Maps are never perfect. Their qualitative rating may be low, for lack of detail, poor methods of presenting relevant data, or for other reasons. On the other hand, scientifically sound maps show the vegetation of the area in a logical and consistent manner, using an unequivocal terminology, and permitting analysis and comparison. Such maps indicate the vegetation in a fashion that allows the reader to visualize it, at least within limits, indicating also that the author of the map has clearly understood the problems which he had to face.

These qualities of a scientifically sound map seem rather a matter

of course and it is perhaps the misfortune of good work that little is said about it because there is little to criticize. But although the qualities of a good map seem obvious, it happens here as so often elsewhere that the obvious is obvious only after it has been pointed out.

The number of maps whose quality leaves something to be desired is considerable. The criticism which must be leveled against these maps could have been avoided in many instances and it is usually a lack of insight and thought on the part of the map compiler that is responsible for the resulting weakness. Many American vegetation maps give one the impression that their respective authors underestimated the problems involved, if they were aware of them at all.

In addition to the various vegetation maps which have been published as a result of scientific investigations and for scientific use, there appeared especially during the last two decades a considerable number of maps which may be termed secondary vegetation maps. Their purpose sets them apart from the others, and this purpose is not a scientific one in the usual academic sense. They are drawn to illustrate specific economically important features.

A fine example is the Forest Type Map of Oregon (U.S.F.S, 1936) which has obviously been prepared with great care. It would be quite inappropriate to measure this map with standards that apply, for instance, to the Patuxent map (1945). For the Patuxent map portrays a scientific research area and must hence be expected to meet scientific standards. But the Oregon map shows forest types in terms which are significant to those who wish to exploit the forests. As a result great emphasis is placed on the forest types which contain merchantable timber, especially if their species produce valuable wood, such as the Douglas fir or the western yellow pine. The importance of such trees is indicated by several height, size and age classes. Less valuable

trees are mentioned in a much more cursory manner, and where no trees occur, everything is shown under the heading of "non-forest land," regardless of whether the vegetation of such areas is grass, sagebrush, or is absent, as in urban areas. This one-sided approach may perhaps shock the scientific investigator but the purpose of the map has nevertheless been fulfilled.

Wieslander (1937, 1949) is the only one in the Forest Service whose work resulted in the development of a genuinely systematized approach to the problems of mapping vegetation and whose maps are comparable to European maps. Although limited to use in California, his work can easily be expanded to apply to other parts of the country. Meanwhile Küchler (1949, 1950) developed the technique of mapping the physiognomy of vegetation for world-wide use. Floristic methods have been highly refined in Europe. There is, therefore, ample material available which can serve as a basis for future vegetation maps in this country.

American vegetation mapping was late in its start and its history reveals all too often that work of doubtful quality found its way into print. However, the interest in vegetation maps has at last been aroused and is certainly increasing. This, therefore, would seem to be the time to promote ideas which will remedy past errors and utilize accumulated experience. For instance, it may be suggested that an organization of properly qualified persons be established to develop and execute plans for a complete scientific mapping of vegetation of the United States on the scale of 1:1,000,000.

Conclusion

For geographers, vegetation will long remain the most absorbing aspect of biogeography, with vegetation maps as the most valuable tool. Recent years have witnessed an extension of American plant geography, made possible

by a growing interest in the subject and a greater output of research papers. The real benefit of these works, however, is not apt to become apparent until some future date.

In the early past, the trend was to accumulate ecological material. Much later, other branches of plant geography, each one separately, walked in that same path of gathering data. This increase in the number of avenues of approach widened the outlook considerably. Now voices are heard demanding the coordination of the various roads into an all-weather highway of comprehensiveness with fewer chances of getting stuck in mud or quicksand because the stability is based on greater catholicity as the chief characteristic of research. The latest trend, as yet only just envolving, differs therefore essentially from the earlier one in that the outlook and the resulting structure of the work change from amassing to coordinating data. The theory of evolution arose from the proper arrangement of innumerable data, independently "discovered" by many biologists. Already, Cain (1944) has fused a variety of phytogeographic ideas and has thus made a major contribution to modern plant geography. Whether plant geography will ever have a Darwin remains to be seen, but the possibility for a parallel development is undeniable.

Now that phytogeography is more readily approached from several sides at once, one looks forward to the evolution of new ideas, new theories, and new concepts. Whether the formulation of such a new trend will ultimately come from pioneers like Cain, Camp, Egler and Raup, or their students, or perhaps from some now living but unrecognized authority is a matter for speculation. At least, the way to some essentially new "Origin of Vegetation" is open to those who are able to amalgamate the various aspects of biogeography with a vivid imagination as they proceed on their road to discovery.

Acknowledgments

An invaluable service is now being rendered to the student of American vegetation by F. E. Egler. Proceeding from the idea that research on vegetation is urgently needed but that such research is impossible without an adequate bibliography, Egler now heads a growing group of collaborators who work on a detailed annotated bibliography of American vegetation literature. Usually each collaborator is responsible for one or more individual states. The series, of which Egler is the editor (and also contributor), is sponsored by the American Museum of Natural History, New York, under the name "The Vegetation Bibliography of the Americas." As this series grows, it cannot help but develop into one of the most valuable tools for the student of American vegetation.

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